Evolution.¹

By Sir OLIVER LODGE, F.R.S.

THE word "evolution" is often employed as an antithesis or opposition idea to creation; and it is quite possible that when Herbert Spencer was trying to extend ideas derived from Darwin as to the natural processes by which species had originated, and to apply them to the production of everything, that some idea of that kind was in his mind. He probably felt that he was exploding the popular idea of a sudden creation, a sudden production of things by a creative fiat, and substituting a long, slow, and gradual process, by which the simple evolved into the complex, and the potentialities latent in the atoms of matter became unfolded, developed, evolved; thus substituting or replacing a personal process, guided by something like will and intention, by an atomic and, so to speak, mechanical operation among the things themselves.

How mind and consciousness could come into such a scheme was scarcely known, though there were and had been guesses about that too; and the doctrines called "parallelism" and "epiphenomenalism" were sustained by different philosophic writers. Indeed, how life, even of the lower organisms, originated, was never answered; and though many attempts were made, all over the world and for centuries, at spontaneous generation (some of them in late years by Charlton Bastian at King's College, London), they never succeeded in producing life except by faulty experimentation. It was gradually established, and accepted by Huxley, that life only proceeded from antecedent life, so far as our experience went: that if all vital germs were excluded, no life, even of the lowest kind, appeared.

It was research on these lines which summoned the great Pasteur from chemistry to biology. It laid the foundation for his theory of disease, and it was the noble work of Lister to apply it with beneficent results to surgery. Thus and by all these channels was emphasised the doctrine of biogenesis: that life alone could produce life. Life produced itself; still, however, in its various forms, by a process of evolution, and by no act of special creation. The vital steps were gradual and could all be followed, once given the germ of life. The origin of life itself was left as an insoluble mystery, or rather as a mystery to be solved by science at some future date. It was thought, at any rate by some, that once life made its appearance in the scheme, the evolution of mind was only a further step in the process. Mind was apparently a stage ahead to which life might aspire, for life in the course of ages might blossom into mind.

The attempt thus to explain evolution as a gradual self-acting process was a legitimate one, and contained, as we now see, many of the elements of truth. It led to a materialistic philosophy, which for a time held the field, and attracted the attention and the enthusiasm of a multitude of workers. It was, however, not the whole truth: it was a working hypothesis. It went a certain distance with success, and only gradually were its weaknesses perceived. It was not so much wrong as incomplete. It sought to account for things it could not account for. But as an intermediate step it was

helpful and stimulating, and invigorated the science of biology with a working hypothesis which has proved of great service. It served as a clue or guiding light among a multiplicity of phenomena which without it had seemed detached and disconnected; and it stimulated observation and experiment to a remarkable degree. It carried workers a long way, and it carried enthusiasts too far. It led to the exclusion of mind or purpose from the universe, and replaced it by mechanism. If a materialistic philosophy had worked, it would have been justified by results. But it was incomplete; and gradually its weaknesses and omissions became apparent; so that by this time, as a complete account of the universe, it is recognised as insufficient and faulty. The mistake—if it can be called a mistake—lay in the thoughts or contentions of those who put it forward as in opposition to the idea of creation, instead of regarding it as a method of creation.

The old idea of creation as a sudden achievement without intermediate steps, without any process that could be followed by the human mind, and without any extensive lapse of time, was seen to be erroneous. Yet, amid much crudity, most of us now perceive that it contains some elements of truth; just as the working hypothesis of mechanical evolution did. The time was not yet ripe for identifying and unifying the two. They seemed to be in the field as opposition theories, one against the other. They seemed to be mutually exclusive; so that if one were accepted, the other must be rejected.

Whether this opposition of the two views was seriously in the mind of the philosophers of that period may perhaps be questioned; in all probability it sometimes was. Among the rank and file it certainly was: many half-educated people leapt to the conclusion that the universe could be explained on mechanical principles and in terms of matter, and that in matter could be found the full potentiality of life and mind and everything that we have so far discovered or experienced in the universe. Whether or not that was the intention of the leaders may well be doubted. Huxley himself made it abundantly clear that in his view a materialistic philosophy had its limits, and that consciousness could not thus be accounted for. Nevertheless the two views, in the popular mind, were in opposition; and it led to alarm among the Churches at the doctrines of Darwinism and at the teachings of evolution generally. This feeling of antagonism between the two views, and the feeling of alarm and dislike of one of them, has survived in certain States of America, and has led to an attempt to suppress the disliked view by legal enactment.

However irrational this procedure may be, there is some excuse for it; and it is possible to regard their conscientious action with sympathy, even though the sympathy is mingled with amusement. Not in that way is truth really served. Freedom is the life-blood of science; and freedom is only consistent with the power of making mistakes and going wrong, as well as with the power of ascertaining truth and going right.

Crudities were not confined to one side of the controversy. Old doctrines of creation were crude; new doctrines of evolution were equally crude: and either

¹ From the Huxley Lecture delivered at Charing Cross Hospital on Thursday, December 3.

side could have their teeth set on edge by the other. Young and enthusiastic teachers, perceiving only one side of the problem, could rush into extremes; could not only uphold their own view, but also could pour scorn upon the other. Since the sectarian differences between religious bodies had led to the suppression of what may be called Biblical teaching in State schools, as the only alternative to strife and sectarian controversy,—since the freedom of the orthodox was limited, and they were prevented from teaching the young their own special and detailed creeds,—it became obnoxious to allow perfect freedom to the opposition side, which took no interest in sectarian controversy, but would gladly sweep away the whole of the doctrines associated in the popular mind with the mysteries of religion. Sectarian differences had limited freedom on one side; it seemed time to limit freedom on the other too; and that, I take it, is the explanation of what otherwise seems an irrational and foolish procedure.

There are, I know, a multitude of people in Great Britain who still feel the fundamental opposition between the two views, and some who in their heart sympathise with the action of those Southern States who have put the law in operation against one of them. There is always some justification for any human action which is well intentioned and sincere, however mistaken it may be. We are all of us constantly making mistakes: the proverb says that "it is human to err." It is part of our training to be able to make mistakes with perfectly good intentions, one of the mistakes being to think that we have an infallible guide when we have not. Infallibility has not been granted to man. We have to make our way among pitfalls and obstacles, to make progress slowly and with difficulty, and gradually to learn what is true by finding what is false; never learning the whole truth—for that we could not apprehend—but making our way towards the truth, in a blundering but persevering manner.

The very documents to which some of the ultra-orthodox pin their faith are full of misstatements and errors committed by humanity in the past; and however full they are of inspiration—as in many parts I am sure they are; much more, as I think, than some educated people are always inclined to admit—yet they are human documents, full likewise of the mistakes, misinterpretations, slips and errors appropriate to the human vehicles through which they have come. It is our business to try to sift the true from the false, the genuine from the mistaken, the misinterpretations of scribes, the faulty reports of occurrences, and thus to dig down to the underlying essence, which gives these documents their supreme value.

The book of inspiration, by which I mean the thoughts of the great thinkers and seers and saints and prophets of all time, is one avenue of truth: the book of Nature, explored by a multitude of energetic workers, that is to say, the book of science, is another. In so far as both are true, they cannot be in opposition. In so far as either is mistaken, opposition is inevitable; and although the virulence of the opposition is now greatly mitigated, and is not fierce and uncompromising, as it was even in the lifetime of some of us, some amount of opposition exists still. Indeed, in the minds of half-educated people its virulence is still manifest, and some fierceness of opposition still subsists to this

day. It is so easy to take one side only of a controversy, to regard that as completely right, and the other as hopelessly and completely wrong. We find this attitude even in party politics. We find it more or less in the forensic activities of counsel in the law courts. It is understood, there, as a method of laying the case before the judge, to whom is left the impartiality of scrutinising the evidence for what it is worth, and coming to a judicial and balanced decision.

We ourselves, however, in our own minds and with our own responsibility, are both counsel and judge. There are moods in which we emphasise one side; there are moods in which we emphasise the other: but ultimately we try to hold a balance between them, and we doubtless hope that our ultimate convictions will be based on the evidence, and will lead to a true and impartial verdict.

My thesis is that there is no essential opposition between creation and evolution. One is the method of the other. They are not two processes, they are one—a gradual one which can be partially and reverently followed by the human mind. We have the right to study the methods so far as we can, the right to probe into the manner by which the manifold things around us are interrelated, and how they have come into their present form. We try to set forth the physical processes in detail, and for that special purpose to limit ourselves to the mechanical, the physical, the chemical, the calculable, and the directly observed, without the least trace of impiety, and without being reasonably accused of denying a great tract of country which is not on our beat, which we are not exploring, and which, though through lack of time and energy we perforce neglect, we do not (if we are wise) ever think of denying.

[Then followed an account of the process of cosmic evolution so far as modern science is able to formulate it, based upon the work of Eddington and Jeans. The question was then raised as to whether a linear process of evolution—a procedure in time with a beginning and an end—was likely to be the last word, or whether there was any way of overcoming the dissipation of energy and prospective stagnation.]

Now consider what happens when light of all kinds, ultra-violet light, X-rays, and all others, encounters a particle of dust, or, in other words, some atoms of matter, which have been driven to the confines of space by the pressure of light. What happens has been investigated in our laboratories, and is known as photo-electricity. An electron jumps out of the atom: the atom is ionised.

This ionisation of matter by light is becoming, or is likely to become, familiar in medicine. The photographic and chemical actions of light are constantly being studied, its action in polymerising sap in the leaves of trees and vegetation generally, the action of light on the skin also, and its familiar though remarkable effect on the nerve-supplied retina of the eye. How are these chemico-physical actions to be accounted for? Surely by the photo-electric property; that is, by the power of waves of the right frequency of vibration to eject an electron from an atom. An immense amount is now known about this process. Electrons are

revolving in fixed orbits inside the atom, as conceived by Prof. Bohr, and under the stimulus of radiation they jump from orbit to orbit as birds jump from perch to perch. An incoming wave can make them hop to a higher twig, or else fly away altogether.

This last process is called ionisation; for the atom, having lost an electric charge of one sign, is now charged with the opposite sign: it is an ion; it is no longer neutral and inert, it is active and chemically fierce; it is no longer satisfied, it seeks to combine with another. Chemical affinity is in full blast, and the molecular changes in protoplasm, in silver salts, and in the leaves of trees, occur. In the retina the nerves are bombarded by the ejected electrons, each striking with an energy appropriate to the frequency of the received vibrations, and thus give the different colour sensations through the extraordinary interpretative power of the mind through its organ the brain.

The destructive influence of this action on micro-organisms such as an anthrax bacilli, when they are exposed to ultra-violet light, is well known; and the health-giving power of these same ultra-violet rays—at present so sadly and wastefully and thoughtlessly obscured by the atmosphere of towns—is constantly receiving more and more expert attention.

Surely here we have a region of physics of great use in preventive medicine: a lavish supply of ultra-violet light is sent us by the sun; it only remains for us to enable this light to reach our bodies and our homes. We know how to generate such radiation in the laboratory also, and can use these rays for curative rather than for preventive purposes. A study of radiation—radiation of all kinds—has proved of late years intensely illuminating. Thereby that mysterious but fundamental entity, the quantum, has been detected; thereby the temperature, the constitution, the age, the speed, the history, of the various cosmic masses has been and is being elucidated; thereby the formation of wood, and the growth of vegetation on which animal life depends, has been explained; and now the sanitary and invigorating and beneficent work of sunlight on the human organism is being more and more appreciated, and more and more studied and applied by those who have the requisite training, who will watch for the dangers of excess, and regulate the appreciation of any kind of ray with patience and wisdom. I hope that a recognition of the electric and ionising power of such rays, which I urge as a reasonable explanation of their chemical and physiological activities, may be a hint in the right direction to those engaged in this work.

Reverting now to what I was beginning to deal with, namely, the hypothetical effect of stray or apparently waste radiation when it reaches the confines of space and encounters the supposed age-long accumulation of cosmic dust, which pictorially and for the present purpose we represent as more localised than it is at all likely to be; it may be said that the light, when it has travelled to those enormous distances, will be too feeble to do anything; but apparently it is not so. The jump of the electron is effected, not by the energy of the light, but by its frequency, its rapidity of vibration; and that is just the characteristic which it will retain unaltered, no matter how far it goes, or how weak it gets. Light of the critical frequency—which depends on the nature of the atom and the position of

the electron in it—will be able to ionise it, however impoverished by wide-spreading the light is.

It is true that the number of electrons liberated depends on the intensity of the light, though the energy of each does not so depend. If the light is very weak, the number of ions formed will be few, but the area available is enormous. Nothing like such an area of matter exists in the visible cosmos. If only one or two ions a second were formed per square kilometre, the loss of matter from millions or even billions of suns could be compensated.

Now consider what happens when an atom is ionised. It has lost a negative charge: it has therefore become a positive ion. The negative charge has gone away, and will attach itself to some other atom, which thereby becomes a negative ion. Sooner or later the two may meet. They will not discharge into each other; that is not what happens; they will combine to form a molecule, a chemical compound. The process of chemistry has begun, under the influence of light.

We are evidently returning to the stage at which we begin the consideration of the course of evolution. Radiation gives up its own being, the energy takes the form of electrical separation. It then takes the form of chemical combination: aggregates of matter are formed. This aggregation may go on until the particles begin to feel the effect of the gravitative attraction of the far-distant cosmos. No longer will the particles be sustained and separated and driven away by light. They are now big enough to have effective weight; and slowly they will begin to make their way back; bringing with them in potential form the lost and radiated energy; and so begin once more the clash of atoms, the formation of nebulae, the birth of stars, and ultimately of planets.

It may even be that fresh matter in the form of electrons and protons can be *generated* by radiation, apart from its photo-electric effect on already existing matter. To me it seems not unlikely. But that is going outside our laboratory knowledge: of that process of "beknotting" in the ether we have as yet no inkling. A knowledge of that may come, but not yet. Meanwhile we have something which, if not sufficient, seems at any rate a step towards reconstruction, rehabilitation, regeneration.

Some may feel this doctrine depressing, and ask: Is there then no progress, no increase of value, no real improvement, nothing but a universal level of uniformity, so that what is always has been and always will be, not only without change and decay, but also without rise and advance? That is not the deduction that we are entitled to make. For remember that we have been dealing with the physical universe only; we have not touched on the universe of mind, soul, spirit, or any of the emotions and faculties of man. We have been studying the course of physical evolution, and have imagined it as evolving in a cycle. I believe that is the essence of the physical universe, to follow a cycle, round and round:—The plant assimilating inorganic materials, elaborating them into food for animals, the animals returning them in the inorganic form, ready for the plant; energy taking the potential form, then the kinetic, then the potential again, and so on alternately for ever; water evaporated, rising as vapour, then falling as rain, getting back into the sea, and being

evaporated again. Everywhere we find a cyclical process in the material universe.

What about the mental universe? Surely there we find growth, development, increase of value, rise in status; the lower organisms becoming intelligent creatures, then developing into man. And what of man? If his death is the end of him, the value of his existence may be doubtful. But if, as I know, that is not the end of him, then there may be infinite progress in store. The cyclical machinery of the physical universe is employed to develop value in the mental and spiritual universe; just as the revolution of a fly-wheel may be the means of turning out a woven fabric

of beauty and design. The fabric will age and turn to dust: so may a picture or a statue. But what about a poem or a piece of music? They have in them the seeds of immortality, and if great enough, will last so long as humanity endures. All things last for ever, if what we have been saying is true; but while the physical things last by a kind of evolution of cyclical change, the evolution of spiritual things has no necessary regress. They advance continually through higher and higher stages towards perfection. This, I take it, is the real meaning of evolution. This is why the physical universe exists. This is the real aim and purpose of the ultimate and infinite term "God."

Surveys of the Great Pyramids.¹

By Sir W. M. FLINDERS PETRIE, F.R.S.

THERE seems a periodicity in the attention to the size of the Great Pyramid: the French survey 1799, Howard Vyse 1838, my survey 1881, and now Mr. Cole's survey in 1925, are at nearly equal intervals. The difficulty in measurement results from the Arab destruction of nearly the whole of the fine sloping blocks of casing, about 3 feet thick, thus leaving the inner core of masonry in steps, and further, the banking of the ruins up to 20 or 30 feet against the faces, which obstructs the base. The last remains of the lowest course of casing are only a short length in the middle of each side, and the purpose of this recent survey was to utilise more of these points of the original casing than had been seen before, such being more accessible since the removal of large quantities of the fragments, for making the road and building an hotel. In 1881 it was a risky affair to sink pits in loose rubbish 20 feet deep; I only escaped burial by a few seconds; seventeen shafts were sunk, but the casing edge was only found once on each side. In 1925 it was possible to uncover the casing over lengths of between 45 and 170 feet on different sides, and the use of such further material was very desirable in order to define the faces more precisely.

The 1925 survey was in two parts: (1) the prolongation of the alignment of the remaining portions of casing out to the corners by theodolite sighting, and (2) the survey of these produced corners by triangulation. The general order of accuracy that should be sought is indicated by the levels of the pavement, of which the mean error is only 0.21 inch; certainly it would be easier to achieve equality of length than of level. The method of setting a theodolite over an estimated edge of sloping casing, and then of telescopic estimation of such an edge at more than 100 feet away, is a risky process on the sand-blasted, pitted and chipped surfaces. The differences between 1881 and 1925 surveys depend on a third of an inch in such estimations. After that, the results depend on the 1925 triangulation for fixing the corner intersections by a chain of eight points joined by a traverse around the pyramid; this had a difference of 9.6" = 2.7 inches if on the whole distance, which was distributed equally in the reduction. The 1881 survey included the whole pyramid in a single triangle, the discrepancies of which averaged

0.04 inch; these station marks can always be re-used, as they were drilled in the rock, and the co-ordinates were all published.

The results of the two surveys are, in inches of length of the side and angular orientation of face:

	1881.	1925.
N. side	9069.4 - 3' 20"	9065.1 - 2' 23"
E. side	9067.7 - 3' 57"	9073.0 - 5' 30"
S. side	9069.5 - 3' 41"	9070.5 - 1' 57"
W. side	9068.6 - 3' 54"	9069.2 - 2' 30"
Mean	9068.8 - 3' 43"	9069.4 - 3' 6"
Mean differences	0.7 12	2.3 1 12

There is a check on the estimated prolongation of the sides in 1925, as there is the 1881 estimate of the planes touching the core masonry. These were:

	1881.	Difference to Casing 1881.	Casing 1925.
N.	9002.3 - 4' 35"	+1' 15"	+2' 7"
E.	8999.4 - 5' 26"	+1' 29"	- 4
S.	9001.7 - 5' 23"	+1' 42"	+3' 26"
W.	9002.5 - 5' 39"	+1' 45"	+3' 9"
Mean	9001.5 - 5' 16"	+1' 33"	+2' 10"
Mean differences	1.0 20	10	1 8

As the planes of the core could be estimated within an inch of variation (= 23") this is a useful check. It shows that the casing was adjusted 1' or 2' differently after the core was built. The divergence of the 1881 casing lines from the core have only 10" irregularity; the 1925 results show 1' 8" of irregularity; as this latter is equal to 3 inches on the length of the side, the core is competent evidence in favour of the 1881 survey. It may also be observed that a building with mean error in level of 0.2 inch is more likely to have a lineal error of 0.7 inch found in 1881 than of 2.3 inch found in 1925.

On all grounds it seems highly desirable to settle more precisely the exactitude of the most accurate human work of such large size. Station marks are needed at the side of each end of the lines of casing observed, to be connected with the more accurate triangulation of the 1881 net, which has less than 0.1 inch probable error in stations. Offsets should be taken between the new stations to the estimated edge of the casing all along. These would show how exactly the straightness was maintained, on which depends all evidence for prolongation of the short lengths of remaining casing.

¹ "Determination of the Exact Size and Orientation of the Great Pyramid of Giza." By J. H. Cole. (Survey of Egypt, Paper No. 39; Government Press, Cairo.) 1925. 8vo. 9 pp. 1 pl. 10 P.T. (2s. 1d.).